FRHAM-TEX™ Cool Suit

Deactivation and
Decommissioning Focus Area

Prepared for
U.S. Department of Energy
Office of Environmental Management
Office of Science and Technology

February 1998

INNOVATIVE TECHNOLOGY
Summary Report

FRHAM-TEX™ Cool Suit

OST Reference # 1854

Deactivation and
Decommissioning Focus Area

Demonstrated at
Chicago Pile 5 (CP-5) Research Reactor
Argonne National Laboratory-East
Argonne, Illinois

Purpose of this document

Innovative Technology Summary Reports are designed to provide potential users with the information they need to quickly determine if a technology would apply to a particular environmental management problem. They are also designed for readers who may recommend that a technology be considered by prospective users.

Each report describes a technology, system, or process that has been developed and tested with funding from DOE's Office of Science and Technology (OST). A report presents the full range of problems that a technology, system, or process will address and its advantages to the DOE cleanup in terms of system performance, cost, and cleanup effectiveness. Most reports include comparisons to baseline technologies as well as other competing technologies. Information about commercial availability and technology readiness for implementation is also included. Innovative Technology Summary Reports are intended to provide summary information. References for more detailed information are provided in an appendix.

Efforts have been made to provide key data describing the performance, cost, and regulatory acceptance of the technology. If this information was not available at the time of publication, the omission is noted.

All published Innovative Technology Summary Reports are available online at http://em-50.em.doe.gov.

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SECTION 1

Technology Summary

Problem

Radiation workers at all U.S. Department of Energy (DOE) sites require some form of protective clothing when performing radiological work. A large number of contaminated facilities at DOE sites are currently or will eventually undergo some form of decontamination and decommissioning (D&D), requiring some type of protective clothing, often in multiple layers. Protective clothing that does not allow perspiration to escape causes heat stress, which reduces worker comfort and productivity.

How it Works

This report describes the FRHAM-TEX Cool Suit™, manufactured by FRHAM Safety Products, which can be used during D&D activities to protect workers from contamination. The suit is a one-piece, disposable, breathable, waterproof coverall designed to permit moisture generated by the worker to be transmitted outside the suit. It cools by transmitting moisture, rather than vapor, to the outside. Constructed of spun-bonded polyester bonded to butylene/poly hydrophilic film, the suit is certified as incineratorable. Figure 1 shows the zip-lock closure system of the suit.

Figure 1. Zip-lock closure system for the FRHAM-TEX Cool Suit™.

Commercial Availability

The FRHAM-TEX Cool Suit™ is readily available from FRHAM Safety Products. Suit styles include coveralls, bagsuits and two-piece wet-suits with hoods. Traditional coveralls were the type tested during the demonstration. The suits are available in petite, small, medium, large, x-large, and jumbo. Correct fit depends on the body size of the worker and/or the type of undergarments worn during D&D activities.

Demonstration Summary

The demonstration was held at the JANUS Reactor D&D Project at Argonne National Laboratory-East (ANL-E) from August 4–7, 1997 during concrete demolition activities. Two workers performing jackhammering, lifting, and moving activities wore the FRHAM-TEX Cool Suits™ and evaluated the suits, using Tyvek® suits as a baseline for comparison. The Tyvek® anti-contamination suit (#14261) is manufactured by Mar Marc, Inc. During the demonstration, it was worn with blue hospital scrubs as modesty garments underneath the coveralls.

Key Results

The key results from the technology demonstration of the FRHAM-TEX Cool Suits™ are as follows:

- The FRHAM-TEX Cool Suit™ has very strong seams, which did not rip while donning or doffing or during heavy work with the jackhammer.
- The FRHAM-TEX Cool Suit™ is made of a strong material, which does not tear as easily as the baseline Tyvek® when snagged.
- The FRHAM-TEX Cool Suit™ was much hotter than the baseline Tyvek® suit; however, the baseline suit was not waterproof and did not provide the same level of protection as the FRHAM-TEX Cool Suit™. Workers noted that they had pools of sweat in their respirators and gloves after working with the FRHAM-TEX Cool Suits™.
- The FRHAM-TEX Cool Suit™ is easier to don than the baseline, is roomier, and allows for ease of movement during work activities.

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Licensing Information

No licensing or permitting activities were required to support this demonstration.

Web Site

The CP-5 LSDP Internet address is http://www.strategic-alliance.org.

Other

All published Innovative Technology Summary Reports are available online at http://em-50.em.doe.gov. The Technology Management System, also available through the EM50 Web site, provides information about OST programs, technologies, and problems. The OST Reference # for the FRHAM-TEX Cool Suit™ is 1854.

Overall Process Definition

The purpose of the anti-contamination suit is to act as a barrier between the worker and the surrounding environment. The demonstration goal was to evaluate the FRHAM-TEX Cool Suit™ with the baseline Tyvek® suit. Parameters compared included

- Ability to protect the worker
- Donning and doffing ease
- Fit, including size, adjustability, slack, and catch/trip hazards
- Comfort, including heat and perspiration, skin sensation, and personal mobility
- Work efficiency factors, including productivity, vision, manual dexterity, communication, and balance
- Durability
- Waste generation

The FRHAM-TEX Cool Suit™ is a one-piece, disposable coverall with a single, front, zip-lock closure. It is constructed of spun-bonded polyester, which is bonded to a butylene/poly hydrophilic film to make the suit breathable and waterproof. The material is designed to allow moisture generated inside the suit to be transmitted through the suit to the outside. A proprietary process is used to heat seal the seams of the suit during manufacturing, which strengthens the integrity of the suit.

In comparison, the baseline suit was constructed of untreated Tyvek® material. Tyvek® is a continuous fiber of high-density polyethylene composed of carbon and hydrogen with a typical polyolefin processing additive. It combines lightweight, durable wearability and high barrier characteristics with low linting and anti-static properties. The baseline suits worn in the demonstration had a sewn seam, which is an overedged, serged seam construction that protects against many dry particulates and light sprays.

The FRHAM-TEX Cool Suit™ has no system operations associated with it. It is a coverall type of clothing that is worn by inserting an individual's arms and legs into the suit and closing by the zip-lock closure. There is no secondary waste associated with wearing the suit. Additionally, the FRHAM-TEX Cool Suit™ is certified incineratorable.

SECTION 3

0Demonstration Plan

The FRHAM-TEX Cool Suit™ anti-contamination coveralls from FRHAM Safety Products were evaluated as part of the Large-Scale Demonstration Project (LSDP) at Argonne National Laboratory-East (ANL-E) in accordance with the *Test Plan for the Demonstration of FRHAM-TEX Cool Suit™ at Chicago Pile 5 (CP-5)*. The suits were tested during the evaluation period of August 4–7, 1997 at the JANUS Reactor D&D Project at ANL-E. The JANUS Reactor was a light-water moderated reactor, which operated at a thermal power range from 20 to 200 kW.

The FHRAM-TEX technology was evaluated against the baseline technology, the Tyvek® anti-contamination suit (#14261) manufactured by Mar Marc, Inc., in the areas of heat stress, cost effectiveness, worker comfort, donning/doffing, durability, and waste generation.

Workers were briefed on the particulars of the demonstration before the start of work. The following steps were performed for each work session in the demonstration:

- Perform daily pre-job briefing for all personnel involved in the demonstration.
- Take area temperature and humidity readings.
- Don the appropriate protective suit.
- Complete the work session.
- Doff the protective suit.
- Take temperature and humidity readings.
- Perform exit interview with the workers wearing the suit.

Activities associated with the demonstration included jackhammering. The work consisted of breaking up concrete with a 90-lb jackhammer and then moving the pieces to the disposal container. The work area contained scaffolding that the workers climbed on, over, and around during the course of the demonstration. Air conditioning was used to reduce the heat stress potential to the workers. The temperature was maintained at 68°F and the humidity at 50 percent.

1Performance of the FRHAM-TEX Cool Suit™

The performance of the FRHAM-TEX Cool Suit™ was determined from questionnaires filled out by the workers who wore the suits during the demonstration. Two men participated in the demonstration, each wearing the baseline suit then the FRHAM-TEX Cool Suit™. The Tyvek® suits were worn the first day to establish the baseline for a 1 h, 15 min with a 40-min break, then again for 1 h, 10 min. The FRHAM-TEX Cool Suits™ were worn on the second day of the demonstration, with both workers initially wearing the suit for 1 h, 20 min. That same day only one of the workers donned the suit a second time to re-enter the area. A 4-h, 40-min time period passed before re-entering the work area to perform D&D activities for 1 h. The worker who did not wear the suit twice on the second day tested it again two days later for a period of 1 h.

A questionnaire was used to obtain information from the workers about the FRHAM-TEX Cool Suit™ compared with the baseline. The results were based on subjective opinions rather than quantitative results. No effort was made to measure stay times or medical conditions (breathing rate, heart rate, blood pressure, core body temperature, skin temperature) of the workers during the demonstration. A summary of the questionnaire results are provided in Table 1. The workers were instructed to rate the

suits on a scale of 1 to 5, with 1 being worse than the baseline, 3 being the baseline value, and 5 being better than the baseline.

Table 1. Questionnaire Summary

ACTIVITY	SCORE 1	SCORE 2	AVERAGE
DONNING/DOFFING			
Ability to manipulate closures	4	4	4.0
Amount of effort required	3	4	3.5
Location of closures (such as in the front)	3	3	3.0
Length of time required	3	3	3.0
SUBTOTAL (baseline = 12)	**13**	**14**	**13.5**
COMFORT			
Body heat	1	2	1.5
Perspiration rate	1	1	1.0
Skin sensation	3	2	2.5
Weight to wear	2	3	2.5
Placement of seams/rivets	3	3	3.0
Personal mobility	4	3	3.5
SUBTOTAL (baseline = 18)	**14**	**14**	**14**
TOTALS (baseline = 30)	**27**	**28**	**27.5**

Both workers stated that the seams of the FRHAM-TEX Cool Suit™ were strong and did not have a tendency to rip during donning and doffing. It was also noted that the suits did not tear as easily as the baseline if snagged on something. Additionally, the suits ranked well for roominess, enabling easier movement, and the zipper design contributed to ease of donning and doffing.

The workers concluded that the FRHAM-TEX Cool Suit™ was hotter than the baseline. More perspiration was produced by the workers wearing the FRHAM-TEX Cool Suit™ than the baseline; however, the Tyvek® suit was not waterproof and did not provide the same level of protection as the FRHAM-TEX Cool Suit™.

In one instance, the material of the suit separated at a point on the upper leg where the jackhammer handle rested against the leg; however, the suit did not rip. This could be attributed to the movement of the jackhammer in possible correlation with the amount of perspiration retained within the suit.

SECTION 4

[redacted]

2Competing Technologies

The competing technologies include other similar types of anti-contamination coveralls produced by various manufacturing companies. The major difference is the type of fabric and the type of seam. FRHAM-TEX Cool Suits™ have a heat-sealed-type seam, which classifies the suits as waterproof, versus typical sewn seams, which are not waterproof.

This report evaluates the FRHAM-TEX Cool Suit™ against the Tyvek® coverall (#14261) manufactured by Mar Mac, Inc. Data comparing the FRHAM-TEX Cool Suit™ to other anti-contamination coveralls is not available.

Technology Applicability

The suits are applicable to work in radioactive environments to prevent the worker from coming in contact with contaminated material. Anti-contamination clothing is an item of standard issue in the D&D industry. The FRHAM-TEX Cool Suits™ could be beneficial due to the strength of the fabric and ability to resist tears better than the baseline. Additional advantages of the FRHAM-TEX Cool Suit™ are roominess, which contributes to ease of movement while performing D&D operations, and ease of donning the suit. Since the suit is waterproof, it provides a greater level of protection than the baseline Tyvek® worn in the demonstration.

SECTION 5

[redacted]

3Introduction

This cost analysis evaluates the cost of the FRHAM-TEX Cool Suit™ and compares it with conventional clothing worn for worker protection, Tyvek®, also known as the baseline suit. This cost analysis considers only the material costs of the worker protection suits. Any productivity loss or gain that is associated with wearing either the FRHAM-TEX Cool Suit™ or the Tyvek® is not considered. Although durations were measured for performing D&D activities with the FRHAM-TEX Cool Suit™ and Tyvek®, definitive and measurable quantities of work (i.e., decontaminating a specific number of square feet) were not measured. Therefore, accurate productivity rates cannot be derived from the data. It was subjectively determined that the FRHAM-TEX Cool Suit™ allows more room for movement but is hotter to wear than the Tyvek®, which is not a waterproof suit like the FRHAM-TEX Cool Suit™.

4Methodology

This cost analysis compares two lightweight worker protection suits—one representing an innovative technology, the FRHAM-TEX Cool Suit™, and the other one representing a baseline technology, the Tyvek® suit. Both suits were demonstrated at ANL-E under controlled conditions, which facilitated observation of the work procedures and typical durations of those procedures. The suits were demonstrated for nearly identical activities. The observed activities consisted of operating a 90-lb jackhammer, climbing scaffolding, kneeling and bending down, and picking up concrete pieces.

The selected basic activities being analyzed were obtained from the *Hazardous, Toxic, Radioactive Waste Remedial Action Work Breakdown Structure and Data Dictionary* (HTRW RA WBS), U.S. Army Corps of Engineers, 1996. The HTRW RA WBS, developed by an interagency group, is used in this analysis to provide consistency with established national standards.

5Cost Analysis

Observed unit costs for both the innovative and baseline suits are presented in Table 2.

Table 2. Summary of Unit Costs Observed During the Demonstration

	INNOVATIVE TECHNOLOGY FRHAM-TEX Suit	BASELINE TECHNOLOGY Tyvek® Suit
Cost Element	**Unit Cost**	**Unit Cost**
Materials Purchase	$32.86/XL suit and $33.50/Jumbo suit ($33.18/suit average)	$4.50/suit

The DOE complex presents a wide range of D&D work conditions encompassing a variety of functions and facilities. The working conditions of an individual job directly affect the manner in which D&D work is performed; and, as a result, the costs for an individual job are unique. The innovative and baseline technologies presented in this analysis are based upon a specific set of conditions or work practices found at the ANL JANUS Reactor and are presented in Table 3. This table is intended to help the technology user identify work differences that can result in cost variances.

Table 3. Summary of Cost Variable Conditions

Cost Variable	FRHAM-TEX Suit	Tyvek® Suit
Scope of Work		
Type and Quantity	D&D work, no specific amount of work was measured	D&D work, no specific amount of work was measured
Location	JANUS Reactor	JANUS Reactor
Nature of Work	Operating a jackhammer, climbing scaffolding, and picking up concrete pieces (68 degrees Fahrenheit with 50 percent humidity)	Operating a jackhammer, climbing scaffolding, and picking up concrete pieces (68 degrees Fahrenheit with 50 percent humidity)
Work Environment		
Worker Protection	Waterproof anti-contamination coveralls with hood, and full-face respirator	Anti-contamination coveralls with hood, and full-face respirator
Level of Radioactivity	Radiation area with airborne contamination	Radiation area with airborne contamination
Work Performance		
Acquisition Means	Material purchase by the site	Material purchase by the site
Production Rates	N/A	N/A
Equipment & Crew	Two Facility Operations personnel in suits with one health physics technician (HPT) providing continuous support.	Two Facility Operations personnel in suits with one HPT providing continuous support.
Work Process Steps	1. Suit-up (don) 2. Enter area and setup 3. Operate jackhammer, climb scaffolding, and lift concrete pieces 4. Un-suit (doff)	1. Suit-up (don) 2. Enter area and setup 3. Operate jackhammer, climb scaffolding, and lift concrete pieces 4. Un-suit (doff)
End Product	Worker protection	Worker protection

6Cost Conclusions

The Tyvek® baseline suits used during the demonstration were an average $28.68 less expensive per suit than the FRHAM-TEX Cool Suits™ ($33.18 was the average cost for the FRHAM-TEX Cool Suit™; the average for the Tyvek® suits was less than $4.50). Considering that one worker may use several suits per day, this cost difference may prove to be significant.

The test workers mentioned that the FRHAM-TEX Cool Suit™ did not seem to tear as easily as Tyvek® when becoming snagged, although the fabric material on one of the FRHAM-TEX Cool Suits™ started to separate when it became wet. These factors seem to offset each other; therefore, it is difficult to judge which suit would have a higher usage rate. In regard to productivity, the FRHAM-TEX Cool Suit™ was considered a much warmer suit to wear; but its waterproofing offered more protection to the worker. Additionally, it was noted that the FRHAM-TEX Cool Suit™ was roomier in the upper body. Determining the applicability of each suit would include a consideration of the necessity of a waterproof suit and the added level of protection it provides.

7 Regulatory Considerations

The regulatory/permitting issues related to use of the FRHAM-TEX Cool Suit™ at the CP-5 LSDP consist of the following:

- Occupational Safety and Health Administration (OSHA) 29 Code of Federal Regulations (CFR) 1926.28, *Personal Protective Equipment*
- OSHA 29 CFR 1910.132, *General Requirements (Personal Protective Equipment)*
- 10 CFR Part 835, *Occupational Radiation Protection*
- DOE CFR Part 745.101, *Protection of Human Subjects*

Disposal requirements/criteria include the following U.S. Department of Transportation (DOT) and DOE requirements:

- 10 CFR Part 71, *Packaging and Transportation of Radioactive Material*
- 49 CFR Subchapter C, *Hazardous Materials Regulations*

Waste generated by the FRHAM-TEX Cool Suit™ demonstration consisted of used suits and was added to the existing waste streams for the CP-5 project. No special waste was generated as part of the demonstration.

Since the FRHAM-TEX Cool Suit™ is worn when decontaminating structures, there is no regulatory requirement to apply CERCLA's nine evaluation criteria. However, some evaluation criteria required by CERCLA, such as protection of human health and community acceptance, are briefly discussed below. Other criteria, such as cost and effectiveness, were discussed earlier in the document.

8 Safety, Risks, Benefits, and Community Reaction

The risk of the FRHAM-TEX Cool Suit™ depends on the suit's ability to transfer heat from the worker to outside the suit. Based on the results of the demonstration, the suit could have an impact on workers' health and safety due to heat stress.

The roominess of the suit enables workers to move about more freely. The strength and durability of the suit also decreases the chances of rips or tears and adds to workers' safety. Additionally, its waterproofing adds a level of protection that the baseline suit does not.

There are no measurable impacts on community safety or socioeconomic issues associated with using the FRHAM-TEX Cool Suit™ versus the Tyvek®.

[redacted]

9 Implementation Considerations

The FRHAM-TEX Cool Suits™ are commercially available and come in a variety of sizes. Due to the heat stress indicated by the workers during the demonstration, the following factors should be considered before implementing the suits: the type of work to be performed, the need for waterproof suits, and the stay time in the suits.

10 Technology Limitations and Needs for Future Development

The technology is limited by heat stress considerations. The FRHAM-TEX Cool Suit™ is still beneficial in situations requiring waterproofing due to its greater durability than the Tyvek® suit. Future development should focus on ways to prevent body heat from building up inside the suit to increase the comfort and efficiency of workers.

APPENDIX A

[redacted]

Hazardous, Toxic, Radioactive Waste Remedial Action Work Breakdown Structure and Data Dictionary, 1996. Headquarters U.S. Army Corps of Engineers, 20 Massachusetts Avenue, N.W., Washington, D.C., 20314-1000.

*Technology Data Report for the FRHAM Safety Products FRHAM-TEX Cool Suit*Ô, CP-5 Large-Scale Demonstration Project, September 1997.

*Test Plan for the Demonstration of FRHAM-TEX Cool Suit*Ô, CP-5 Large-Scale Demonstration Project, August 1997.

APPENDIX B

ACRONYMS AND ABBREVIATIONS

ANL-E	Argonne National Laboratory-East
CFR	Code of Federal Regulations
CP-5	Chicago Pile-5
D&D	decontamination and decommissioning
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
FETC	Federal Energy Technology Center
HPT	Health Physics Technician
HTRW	Hazardous Toxic Radioactive Waste
kW	kilowatt(s)
lb	pound(s)
LSDP	Large-Scale Demonstration Project
OSHA	Occupational Health and Safety Administration
RA	Remedial Action
WBS	Work Breakdown Structure